Bringing Patterned Media to Production with Value Added Metrology

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Overview

- Introduction
  - AFM Scan Modes
  - New Nanotrench
- Pattern Media Metrology
  - Requirements
  - Depth & Defects
  - Imprint Metrology
- Wafer Metrology
  - Requirements
  - 3D Metrology
  - Imprint Metrology
- Summary
## Wide Range of Data Storage Metrology Solutions

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<th>Wafer 3D Metrology</th>
<th>Media Metrology</th>
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<td>Failure &amp; Defect Characterization</td>
<td>CMP Metrology</td>
<td>Wafer Trench Metrology</td>
<td>Media R&amp;D Metrology</td>
<td>PTR Metrology</td>
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<td>Worlds Most Advanced AFM</td>
<td>In-Line CMP Metrology</td>
<td>In-Line 3D Metrology</td>
<td>Media/BPM Metrology</td>
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<td>Widest range of AFM techniques</td>
<td>Complete CMP Metrology</td>
<td>Non destructive 3D Metrology</td>
<td>Resist &amp; Alumina</td>
<td>Optical - High throughput in-line metrology</td>
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</table>

- **Dimension AFP**
  - CMP Metrology
  - In-Line CMP Metrology
  - Complete CMP Metrology Solution

- **InSight 3DAFM**
  - Wafer Trench Metrology
  - In-Line 3D Metrology
  - Non destructive 3D Metrology

- **Dimension Icon**
  - Media R&D Metrology
  - Media/BPM Metrology
  - Resist & Alumina

- **Vx200 PTR & Optical Profiler**
  - PTR Metrology
  - AFM - Golden Reference
  - Optical - High throughput in-line metrology
**Advanced AFM Modes for Metrology**

### Tapping Mode
- Non-destructive, high resolution imaging
- Constant scan rate
- Tip lifetime > 100’s sites

#### Topography & Defects

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#### Deep Trench Mode
- Non-destructive high resolution depth metrology
- Adaptive scan rate matches sample structure.
- Tip lifetime > 1000’s sites

#### Production Depth & Sidewall Angle

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### Critical Dimension AFM
- Non-destructive, high resolution sidewall imaging
- Scanner servo’s in X-Z & Y-Z Direction. Adaptive Scanning
- Tip Lifetime > 1,000 sites

#### CD, LER & Sidewall metrology

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- **SNL Probes**
- **CNT Probes**
- **New CDAFM Probes**
New NanoTrench Mode for DTM Metrology

- NanoTrench skillfully combines HarmoniX & TappingMode to create a powerful new AFM mode

- Data shows high resolution, precise depth metrology of BPM/DTM media features

- Lower Measurement Cost
  - Enables small feature measurement with low cost SNL probes from Veeco Probes
  - Significantly improves tip lifetime

Scan Direction

HarmoniX constantly monitors the tip surface interaction (B-C)

NanoTrench starts at (B) probe entering transition

SNL Probes
Improperly Operated Tapping Mode

Tip radius increase from 11 nm to 16 nm in 20 frames

Properly Operated Tapping Mode

Tip radius did not show any change

Scan size 1.5 um for all the images, height scale is 100 nm
NanoTrench Tip Lifetime

Continuous scanning on the rough surface for 66 hours, hundreds of frames. Tip radius maintains 7.5 nm throughout the process.

- Nanotrench mode controls tip/surface interaction peak force directly with high accuracy.
- This force control assures that the interaction is well below fracture limit of Si tips.
Patterned Media Process Flow

Process Steps:
- Magnetic layer deposition
- Patterning & Media Etch
- Gap fill
- Planarization
- Lubrication

Metrology Steps:
- Roughness & Defects
- Depth, CD, SWA, LWR, Defects on Resist & Media
- Roughness, Depth & Defects
- Roughness, Defects, Adhesion Magnetic Properties
- Roughness, Friction, Defects

Advanced metrology for resist profiles, trench profiles, planarization, defects, and material characterization
Patterned Media Metrology with Advanced AFM Modes

- Patterned media metrology requirements

- Small feature
  - Depth, Sidewall Angle, CD
  - Defect Review
  - Residual resist thickness

- TEM/SEM cross-sectioning is labor-intensive and destructive and takes too much time

- AFM provides immediate feedback of results
Imprint Disk Metrology – NanoTrench

- 300 nm x 150 nm
- 32 lines

Low Cost SNL Probes demonstrate low probe wear over 90 images x 3 sites <1nm

Repeatability Data

<table>
<thead>
<tr>
<th>Run</th>
<th>Normalized Depth (nm)</th>
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<tr>
<td>1</td>
<td>-0.39</td>
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<tr>
<td>2</td>
<td>0.01</td>
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<tr>
<td>3</td>
<td>0.11</td>
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<tr>
<td>4</td>
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<tr>
<td>5</td>
<td>0.01</td>
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<td>6</td>
<td>0.51</td>
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<tr>
<td>7</td>
<td>-0.19</td>
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<tr>
<td>8</td>
<td>0.21</td>
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<tr>
<td>9</td>
<td>-0.09</td>
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<tr>
<td>10</td>
<td>0.01</td>
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<tr>
<td>3σ</td>
<td>0.74</td>
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</table>

NanoTrench & SNL Probes
High Probe Lifetime
Pattern Media Post NIL

- **Probe Used**
  - SNL (silicon tip on silicon nitride cantilever)

- **Scan Conditions:**
  - Nano Trench Mode
    - Scan size: 300nm x 300nm
    - 512 x 512 lines
    - 0.44Hz

- **Tests Conducted**
  - Capability
    - Depth measurement
### Bit Patterned Media – CDAFM Mode

<table>
<thead>
<tr>
<th>Etch Structures</th>
<th>Precision</th>
<th>Offset</th>
<th>Slope</th>
<th>TMP</th>
<th>FMP</th>
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<tbody>
<tr>
<td>Nested Space - Etch</td>
<td></td>
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<tr>
<td>InSight #105</td>
<td>1.478</td>
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<td>Space End - Etch</td>
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<tr>
<td>InSight #105</td>
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<tr>
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<tr>
<td>InSight #105</td>
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<td>Via - Etch</td>
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<tr>
<td>InSight #105</td>
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<td>0.999</td>
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<table>
<thead>
<tr>
<th>Resist</th>
<th>Precision</th>
<th>Offset</th>
<th>Slope</th>
<th>TMP</th>
<th>FMP</th>
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<th></th>
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</thead>
<tbody>
<tr>
<td>Line End - Resist</td>
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<td></td>
<td></td>
<td></td>
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<tr>
<td>InSight #105</td>
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<tr>
<td>InSight #103-Demo</td>
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<td>1.002</td>
<td>3.482</td>
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</tr>
<tr>
<td>Via - Resist</td>
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<td></td>
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<tr>
<td>InSight #105</td>
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<td>0.995</td>
<td>3.705</td>
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</tbody>
</table>

- Precision of multiple feature sizes in one run 50nm-150nm
- Wafer ran 3x on each tool
- Includes process variation and variety of feature shapes
The Nanoimprint sample was scanned with a CDP-15 tip. The scan demonstrates approximately 3nm bottom travel. 3nm BTD & 15nm probe diameter = 18nm trench width. The trenches are nominally 22nm top CD x 100nm deep. CDP15C probe is available for advanced development work.
Nanoimprint Linear Correlation: CDAFM Bottom CD to CDSEM

CDAFM correlates to CD SEM

Insight AFM Bottom CD to SEM CD

\[ y = 0.9727x + 2.041 \]

\[ R^2 = 0.9994 \]
DTM Defect Review Imaging

- Many types of defects in media (physical, magnetic)
- Defects in manufacturing are a significant limiter to yield
- Automated import of defects
- Contamination/defects can be imaged & measured from imported defect review file
InSight™ 3DAFM Wafer Metrology

InSight 3DAFM
Depth - 270 sites/hr
CD – 100 Sites/hr

Isolated 100nm Line
5 μm Width, 36 lines, Excellent Image stability
Principle of 3D AFM Metrology

- A flared tip follows the contour of features
- Probe is scanned by piezo X,Y, stage
- Data point spacing 0.1-1.0nm
- Undercut or re-entrant features can be measured
- 3D images is created by multiple 2D line scans

In a **single** scan the 3D AFM provides:

- Top, mid, and bottom CD
- Depth/Height
- Sidewall angle (left and right)
- Sidewall profile
- Line width roughness
- Sidewall roughness
TEM Level Profile Accuracy

<table>
<thead>
<tr>
<th>Average CD Bias (TEM - AFM) using TSE</th>
</tr>
</thead>
<tbody>
<tr>
<td>CD-Trident</td>
</tr>
<tr>
<td>Bias</td>
</tr>
<tr>
<td>Average</td>
</tr>
<tr>
<td>Std Deviation</td>
</tr>
</tbody>
</table>

Excellent Correlation to TEM with 1.0nm Offset
21 data sets. Careful selection of TEM & AFM sites

- Tip Shape Extraction removes tip shape from measured profile
- Data shows excellent correlation to T.E.M. for Profile and CD bias within LER of sample

Over-etched Sample for Testing Purposes
Blue Line is the Average 3DAFM Profile TEM Image

T.E.M. of multiple test lines – 21
Damascene Trench Metrology

Lithography → Post-Etch → Ru Deposition

Probe to Probe Repeatability (3σ)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Height (nm)</th>
<th>Top Width (nm)</th>
<th>Middle Width (nm)</th>
<th>Bottom Width (nm)</th>
<th>Left Angle (°)</th>
<th>Right Angle (°)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Probe to Probe</td>
<td>0.64</td>
<td>1.16</td>
<td>1.12</td>
<td>1.51</td>
<td>0.20</td>
<td>0.18</td>
</tr>
</tbody>
</table>

CNP500 Probes demonstrate over 5000+ measurements

Critical Requirements
- Trench Profile
- Width, Depth,
- Sidewall Angle (SWA)
- Sidewall Roughness (SWR)
- Line Width Roughness (LWR)
PMR Pole Tapering and Edge Features:

Critical Requirements
- Edge Profile
- Height
- Sidewall Angle

Normalized Angle Summary

<table>
<thead>
<tr>
<th></th>
<th>Site01</th>
<th>Site02</th>
<th>Site03</th>
<th>Site04</th>
</tr>
</thead>
<tbody>
<tr>
<td>Min</td>
<td>-0.14</td>
<td>-0.17</td>
<td>-0.23</td>
<td>-0.21</td>
</tr>
<tr>
<td>Max</td>
<td>0.18</td>
<td>0.20</td>
<td>0.12</td>
<td>0.15</td>
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<tr>
<td>Mean</td>
<td>0.00</td>
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<td>0.00</td>
</tr>
<tr>
<td>3σ</td>
<td>0.38</td>
<td>0.35</td>
<td>0.32</td>
<td>0.31</td>
</tr>
<tr>
<td>Range</td>
<td>0.32</td>
<td>0.37</td>
<td>0.35</td>
<td>0.37</td>
</tr>
<tr>
<td>Var</td>
<td>0.02</td>
<td>0.01</td>
<td>0.01</td>
<td>0.01</td>
</tr>
</tbody>
</table>

Normalized Angle Pooled Repeatability (3σ)

Pooled Repeatability: 0.34

CDAFM Mode with 10 deg Angled FIB Probe
Summary

- New NanoTrench AFM Mode provides high resolution AFM metrology for Patterned Media on Dimension Icon AFM
  - Depth metrology on BPM/DTM structures
  - Low Noise Defect metrology

- 3DAFM metrology provides unique 3DAFM characterization and production monitoring of critical metrology
  - Non-destructive direct measurements
  - Delivers results within minutes without need for sample preparation or cross sectioning
THANK YOU